CLAIMS

What is claimed is:

1. A freeze tolerant fuel cell power plant (10) for generating an electrical current from hydrogen containing reducing fluid fuel and oxygen containing oxidant reactant streams, the plant comprising:

a. at least one fuel cell (12) having a proton exchange membrane electrolyte (19);

b. a coolant loop (42) including a porous water transport plate (44) secured in heat and mass exchange relationship within the fuel cell (12), a coolant circulating means (46) secured to a coolant passage (68) in fluid communication with the porous water transport plate (44) for circulating a coolant through the plate (44) and for transferring water into or out of the plate (44) with the coolant, coolant heat exchanger (52) means secured to the coolant passage (68) for removing heat from the coolant, an accumulator (66) means secured in fluid communication with the coolant passage (68) for storing the coolant and water; and,

c. wherein the coolant is a two-component mixed coolant circulating through the coolant loop (42), the two-component mixed coolant consisting of a water immiscible fluid component and a water component.

2. The freeze tolerant fuel cell power plant (10) of claim 1, wherein the two-component mixed coolant consists of between 50 and 98 volume percent of a water immiscible fluid component and between 2 and 50 volume percent of a water component.

3. The freeze tolerant fuel cell power plant (10) of claim 1, wherein the two-component mixed coolant consists of between 80 and 95 volume percent of a water immiscible fluid component and between 5 and 20 volume percent of a water component.

4. The freeze tolerant fuel cell power plant (10) of claim 1, wherein the water immiscible fluid is selected from the group consisting of silicones, substituted silicones, siloxanes, polysiloxanes, substituted siloxanes or polysiloxanes and mixtures thereof.

5. The freeze tolerant fuel cell power plant (10) of claim 1, wherein the water immiscible fluid is selected from the group consisting of perfluorocarbons, hydrofluoroethers and mixtures thereof.

6. The freeze tolerant fuel cell power plant (10) of claim 1, wherein the water immiscible fluid is selected from the group consisting of alkanes, alkenes, alkynes having six or more carbon atoms and mixtures thereof.

7. The freeze tolerant fuel cell power plant (10) of claim 1, wherein the water immiscible fluid has a freezing temperature equal to or less than minus ten degrees Celsius and has a surface tension of less than or equal to 35 dynes/cm.

8. The freeze tolerant fuel cell power plant (10) of claim 1 further comprising a two-component coolant mixing system, including:

a. a coolant diversion valve (70) for selectively directing none, all or a portion of the two component mixed coolant to flow from the coolant loop (42) to the accumulator (66)

means;

b. a water immiscible fluid feed valve (72) secured in fluid communication between the coolant loop (42) and the accumulator (66) means for selectively directing flow of the water immiscible fluid from the accumulator (66) means into the coolant loop (42);

c. a suction generating means (74) secured in fluid communication between the coolant loop (42) and the accumulator (66) means for applying a suction force to the accumulator (66) means for withdrawing the water component of the two-component fluid from the accumulator (66) means into the coolant loop (42); and,

d. a mixer (76) secured in fluid communication with the coolant loop (42) for mixing the water component with the water immiscible fluid within the coolant loop (42).

9. The freeze tolerant fuel cell power plant (10) of claim 8, further comprising a mixing system by-pass valve (73) secured in fluid communication with the coolant passage (68) that selectively directs the coolant from the coolant passage (68) into the accumulator (66) by-passing the mixing system (69).

10. The freeze tolerant fuel cell power plant (10) of claim 1, further comprising:

a. a plurality of fuel cells (104A, 104B, 104C, 104D) cooperatively disposed in a fuel cell stack assembly (102);

b. a plurality of porous water transport plates (106A, 106B, 106C, 106D) secured in heat and mass exchange relationship with the fuel cells (104A, 104B, 104C, 104D) within the cell stack

assembly (102);

c. a high-volume coolant inlet manifold (108) defined within the cell stack assembly (102) for directing flow of the two-component mixed coolant through the plurality of water transport plates (106A, 106B, 106C, 106D) into a coolant exhaust passage (48) of the coolant loop (42);

d. a coolant by-pass line (112) secured between the high-volume coolant inlet manifold (108) and the coolant exhaust passage (48); and,

e. wherein the high-volume coolant inlet manifold (108) is dimensioned to receive and direct to the coolant by-pass line (112) a coolant flow rate that is at least five times a coolant flow rate of coolant flowing through the plurality of water transport plates (106A, 106B, 106C, 106D) from the high volume coolant inlet manifold (108) to the coolant exhaust passage (48) to enhance mixing of the two-component mixed coolant flowing through the cell stack assembly (102).

11. The freeze tolerant fuel cell power plant of claim 1, further comprising an antifreeze coolant loop (54) for circulating an antifreeze coolant through an antifreeze coolant passage (56), an antifreeze coolant pump (58), the coolant heat exchanger (52), and an antifreeze coolant radiator (60), for removing heat from the coolant heat exchanger (52) and the antifreeze coolant.

12. The freeze tolerant fuel cell power plant (10) of claim 1, further comprising a heat-exchange by-pass valve (88) secured in fluid communication with the coolant passage (68) and with a heat-exchange by-pass line (90)

for selectively directing the coolant to by-pass the heat exchanger (52) and flow back into the coolant passage (68).

13. A method of operating a freeze tolerant fuel cell power plant (10), the power plant (10) including at least one fuel cell (12) having a proton exchange membrane electrolyte (19), a coolant loop (42) including a porous water transport plate (44) secured in heat and mass exchange relationship within the fuel cell (12), a coolant circulating means (46) secured to a coolant passage (68) in fluid communication with the porous water transport plate (44) for circulating a coolant through the plate (44) and for transferring water into or out of the plate (44) with the coolant, coolant heat exchanger (52) means secured to the coolant passage (68) for removing heat from the coolant, the method comprising the steps of:

a. securing an accumulator (66) means in fluid communication with the coolant passage (68) for storing the coolant and water;

b. circulating a two-component mixed coolant through the coolant loop (42), wherein the two-component mixed coolant consists of a water immiscible fluid component and water component;

c. separating the two-component mixed coolant into the water immiscible fluid component and water component within the accumulator (66); and,

d. then directing excess fuel cell (12) product water from the water component of the accumulator out of the accumulator (66).

14. The method of claim 13, comprising the further step of mixing the two-component mixed coolant by diverting a portion of the coolant to flow through the accumulator

while directing another portion of the coolant to flow through a suction generating means (74) secured in fluid communication with the coolant loop (42), drawing a portion of the separated water component of the coolant from the accumulator (66) through the suction generating means (74) to mix with the coolant, directing the coolant to flow through a mixer (76) secured in fluid communication with the coolant loop (42), and directing a portion of the separated water immiscible fluid component of the coolant from the accumulator (66) to mix with the coolant.

15. The method of claim 14, comprising the further step of shutting down the freeze tolerant fuel cell power plant (10) by, after the mixing the two-component mixed coolant step, disconnecting an electrical load from the fuel cell (12), then directing all of the coolant to by-pass the suction generating means (74) and mixer (76) and to flow into the accumulator (66), then directing the separated water immiscible fluid component of the coolant to flow from the accumulator (66) through the coolant loop (42) and water transport plate (44) to displace water within the coolant loop (42) and plate (44) into the accumulator (66), then shutting off the coolant circulating means (46), and then opening a coolant loop drain vent valve (86) to drain coolant within the coolant loop (42) and water transport plate (44) into the accumulator (66).

16. The method of claim 15, comprising the further step of starting up the freeze tolerant fuel cell power plant (10) in sub-freezing ambient conditions by, after the opening the coolant loop drain vent valve (86) step, closing the coolant loop drain vent valve (86), then supplying reactants to the fuel cell (12), connecting the

electrical load to the fuel cell (12), then circulating the separated water immiscible fluid component of the coolant from the accumulator (66) through the coolant loop (42) and water transport plate (44) and then through the accumulator (66) to melt a frozen water component of the coolant within the accumulator (66), and then mixing the two-component mixed coolant according to the steps of claim 14 whenever a temperature of the fuel cell (12) is above freezing.